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A series of experiments to be performed with small apparatus by students is presented. Preparation of data sheets and analysis of findings are encouraged. In the category of matter and molecules, the concept to be developed is the determination of whether there are empty spaces in air and in liquids. Experiments with inertia, the law of springs, density, cohesion-adhesion, surface tension, capillary action, viscosity, and diffusion are outlined. To study behavior of fluids, directions are given for experiments on the Archimedes Principle, law of flotation, specific gravity, air pressure, barometer, siphon, and model water pump. For the study of the mechanics of solids, the student is encouraged to generate his own research projects in order to best learn the theory and method of operation. A minimum of instruction should be given by the teacher for this unit. The experiments involve the "resolution of forces using a resolution of forces board," and the movements of forces using a meter stick, a pivot point, the inclined plane, simple and compound pulleys, feather and coin demonstrations, and the pendulum.							
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NOVA SCIENCE UNIT

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You are about to embark on a series of experiments with small apparatus. Most schools do not allow their student to do these experiments for several reasons. We are assuming that our students at Nova will not disappoint us in any of these.

Schools work on a limited budget. They cannot afford to buy this equipment and have it abused by the students. It is your responsibility to be careful with it and see that it is returned to the proper place clean and in good condition. Carelessness on the part of anyone will result in hardship for all. When the equipment is gone, there won't be any more, so many students will be forced to do without.

Even if you take the attitude that "so what? I'll be done with it, anyway", you will suffer because some will have to be replaced, thus limiting the money that we could have spent on you.

There are many of you and only one teacher. You cannot have the full attention of the teacher at all times. We have spent considerable time in the preparation of this material in order to help you understand it. The units that preceeded it were designed to aid you in this unit. Do not forget what you learned. Prepare your data sheets. Analyze your findings. You will get from this whatever you put into it.

I Matter and Molecules

Concept: Are there empty spaces in air?

Are there empty spaces in liquids?

- A. Push the open end of a test tube down into a container of water and observe what happens to the space occupied by the air. Do you think air particles may have been pushed into spaces between other air particles.
- B. Fill a small container with water. Be sure the container is full to the brim. Gently sift salt into the water and observe what happens.
- C. Fill a tube half with water and half with alcohol. Invert the tube and shake. Record your observations of the total volume before and after shaking.

From your observations what conclusion can you reach regarding possible space between particles of matter. In your notebook start a list of the properties of the physical world around you as you observed them in this experiment and those that will follow.

Inertia

Many of you have observed that an object that is at rest tends to remain at rest unless some outside force acts on the object. Also a moving object tends to keep moving. Have you ever tried to stop a moving car? This property of matter is called inertia. When brakes are applied to a moving car, the passengers tend to keep moving toward the front of the car. When the car starts with a jerk, they are pressed against the back of the seat.

- a. Suspend a heavy weight and with a light cord try to jerk it into sudden motion. Swing the weight widely and try to jerk it to a sudden stop. Record your observations.
 - b. Place a coin on a card across a drinking glass; then snap the card off the glass. Record your observations.
 - c. Suspend a weight by a cord and attach a piece of the same cord below the weight. Jerk down on the lower cord and see which cord breaks. Try it again by pulling slowly on the lower cord to see which one breaks.
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Summarize your observations into a conclusion and record in your notebooks.

Law of Springs

Most of you have been to the store and seen merchandise sold by the pound. Candy and meats are sold this way. This merchandise is placed on a nice shiny scale and weighed but have you ever wondered how this scale works? The following experiment might help you understand the operation of a balance.

- a. Suspend a light spring or a spring balance with the scale covered by tape.

Hang on it a weight that will extend the spring a measureable distance.

Hang on more equal weights one at a time, measuring the increase in spring length each time.

- b. Repeat A, using different sizes of rubber bands in place of the spring.

- c. Clamp a light stick (yardstick) at one end in a horizontal position.

Stand a ruler vertically at the free end. Hang equal weights, one at a time, on the free end and note how far each one lowers this end.

- d. Repeat part c using a long piece of light glass tubing and smaller weights.

In each case did a deformation (strain) take place? Were the strains proportional to the forces (weights) applied?

Impenetrability and Density

In previous work we have mentioned density as a property of matter. We did not learn how to measure this property. Since couple of experiments that will teach us what is meant by density.

- a. Fill a large graduated cylinder half full of water and mark the water level with a rubber band. Put in several pieces of like metal. As each piece is dropped in how does the water level change? Why does this change take place? How much change takes place? Formulate an explanation as to why the things you observe take place.
 - b. Determine the mass of a metal object small enough to slide easily into a large graduated cylinder. Partly fill the cylinder with water and record the volume of water it contains. Lower the metal into the cylinder and again read the water level in the cylinder. How can you find the volume of the metal? What property of matter are you taking advantage of?
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1. From you data calculate the density of the metal. This might require some research on your part to learn how.
 2. In what units will you express the density?

Molecules and Their BehaviorCohesion-Adhesion

You may have noticed that objects stick together under certain conditions. Have you ever tried to pick up a smooth piece of metal from a wet surface? Have you ever tried to separate materials that have been glued together? If you have, you've noticed some force holding these things together and resisting any attempt at separation. A few simple experiments should make these forces clearer to you.

- a. Cement a wire hook to the center of a small glass plate using sealing wax.

Hang the plate on a light spring or rubber band, and lower it until it lies flat on clean water. Using a ruler as a scale mark the bottom of the spring or the rubber band. Then pull gently until the plate is free from the water noting how far you stretch the spring or rubber band. While you are still pulling consider whether water sticks to glass and whether water sticks to water. After the plate is free examine it to see whether water holds onto glass more strongly than it holds onto the water in the dish.

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The properties of matter we have studied are called cohesion and adhesion.

Spend some time in research work and determine which is which.

- b. Repeat, using mercury instead of water. If no mercury is found on the glass what conclusion can you reach?
- c. Try drops of water and of mercury on a clean table. What can you conclude from your observation?
- d. Repeat c using a clean copper plate instead of the table top.

Surface Tension

- A. Bend a piece of wire into a ring about 2" in diameter; provide with a handle. Make a loop of thread about an inch long and suspend it in the wire ring. Dip the ring and loop in a dish of soap solution and draw it out in such a way as to leave a soap film across the ring. Thrust a hot wire into the film in the loop of thread. What happens? Why?
- B. Whip up the soap solution to a froth and get a film of froth across the bowl of a common clay pipe or thistle tube. Blow the bubble out to fair size. Stop blowing and note any change in size of the bubble and its final position. Explain.
- C. Repeat B using a glass funnel instead of the pipe.
- D. Repeat D but detach the bubble from the pipe. Note and explain the shape.
- Try to explain your observations by considering the surface of the film to be like a stretched rubber sheet.

Capillary Action

- A. Stand different-sized glass tubes in clean water in one beaker and in mercury in another beaker. Hold the tubes in such a way that you can see what happens inside the tube. Try the tubes in hot water as well as cold.
- B. Try blotting paper, newspaper and writing paper in colored water
- C. Try absorbent cotton and ordinary cotton in water. If the liquid wets the tube, is it raised or depressed?

Does the liquid climb higher in large tubes or in small ones?

How does the temperature of the liquid affect its change of level.

Viscosity

In three separate glass tubes of large diameter place alcohol, water, and oil. Using a stop watch determine the time it takes a steel ball to descend through the liquid. Explain your observations in terms of molecules.

Diffusion

At one end of the room place an open container of Ammonia water. Place several students at the other end of the room. Record their reactions. How long did this take. Try this with water. Any results? Try it with perfume if some student will donate some. What results? Explain these observations in terms of molecules.

II. Behavior of Fluids

A. Push the handle of a glass demonstration water pump filled with water. What do you observe? What transmits the pressure the pressure of the piston to the water at the nozzle end?

B. Fasten a cord with sealing wax to the center of a mica disk large enough to cover the bottom of a glass cylinder. Pass the cord up through the cylinder and, holding the disk against the cylinder, press that end of the cylinder down into a jar of water. Let the cord hang loosely in the cylinder, and pour colored water into the cylinder until the dish falls off. How high was the water in the tube when the disk fell off? How did its downward pressure then compare with the upward pressure against the disk? At any given depth, how does upward pressure in a liquid compare with downward pressure?

Archimedes Principle

A. A brass cylinder is made so as to fit exactly into a bucket. Hang the bucket and cylinder on a hook beneath one pan of the balance. Counterpoise the bucket and cylinder by putting weights onto the other pan. Immerse the cylinder in water. Which side is now lighter? Pour water into the bucket until the balance is restored and note that the bucket is not just full.

Since the cylinder exactly fits the bucket, the volume of water poured into the bucket equals that of the water displaced by the cylinder. Did the immersed cylinder appear to lose weight? How much is this displacement? Do you see any relationship between the buoyancy and the displacement. What law is this?

Law of Flotation

Place an overflow can on a dial scale and fill the can with water so that a little runs out the overflow. Adjust the dial of the scale so that the pointer is at zero.

Float a wooden block in the can and let the overflow water run into a bucket or beaker. What movement of the pointer do you notice? What is the position of the pointer when the overflow ceases? How does the weight added to the can by putting in the block compare with the weight lost by water flowing out of the can?

Specific Gravity of a Heavy Solid

- A. Weigh a piece of metal in air. Record this information and then weigh the metal immersed in water. Record this weight. How much does the piece of metal weigh? How large a volume of water is displaced? How heavy a volume of water is displaced? How do you know this? Is the metal heavier or lighter than the water? How many times as heavy? What is your answer called?
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Specific Gravity - Bottle Method

- A. Weigh a specific gravity bottle empty, and then filled with a solution furnished by your teacher. What weight is found by subtracting the weight of the empty bottle from the weight of the filled bottle? Weigh the bottle filled with water. How can you find the weight of an equal volume of water? What is found by dividing the weight of the solution by the weight of an equal volume of water?
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Specific Gravity - Hydrometer

- A. By means of hydrometers determine the specific gravity of various liquids, such as water, a copper sulfate solution, a lubricating oil, kerosene, and a sulfuric acid such as used in storage batteries. How does the specific gravity of a liquid affect the depth to which a hydrometer sinks? Why?

Air Pressure

A. Fill a glass cylinder with water to the brim. Wet a piece of cardboard and lay it carefully on top of the water in the cylinder. Hold the card, invert the cylinder slowly, and then remove your hand. Why does not the card fall?

B. Boil a little water in a kerosene can, tightly closed except for the rubber on the spout. When steam comes out freely seal the can and stop heating. Pour cold water on the outside to condense the steam on the inside. What is the pressure inside the can when the steam condenses? What crushes the can?

The Barometer

- A. Fill a 3 foot glass tube, sealed at one end, with mercury. Closing the open end with the thumb slowly invert the filled tube and put the lower end below the surface of some mercury in a dish. Remove the thumb. What does the mercury in the tube do? At about what height does it stand above the level of the mercury in the dish? Why does it not fall farther? What is the empty space left at the top of the tube called?
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- B. Repeat the above using a two hole stopper into a jar of mercury. Provide a glass tube outlet by means of which the pressure in the glass jar can be changed. Try several ways of changing the pressure in the jar and record your observations.
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The Siphon

- A. Fill a short length of rubber tubing with water, keeping the ends pinched shut. Bend the tube into an inverted U, and release the ends. Through which end does the water always empty?

Repeat, holding the end of the shorter tube under water. When the ends are freed notice what happens to the water.

Vary the length of the hose and record your observations.

Model Water Pump

- A. Obtain from your instructor a model water pump. Use this pump and study its action. After studying this instrument, record all your observations and draw a conclusion regarding the operation of this pump.

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III. Mechanics of Solids

A. This experiment is concerned with mechanics of solids and should be given to the student as research projects so that they can obtain the theory and method of operation. A minimum of instructions should be given by the teacher.

1. Resolution of forces using a resolution of forces board.
2. Movements of forces using a meter stick and a pivot point.
3. Inclined plane
4. Pulleys - simple and compound
5. Feather and coin demonstration
6. Pendulum